

RU 663

FEB 24 1988

APPENDIX X

CHARACTERIZATION OF SUMMERTIME ICE CONDITIONS
IN THE ALASKAN BEAUFORT SEA

by

W.J. Stringer and J.E. Groves

Characterization of Summertime Ice Conditions in the Alaskan Beaufort Sea

INTRODUCTION

The summertime extent and concentration of sea ice in the vicinity of Alaska is a matter of concern from several OCSEAP* points of view. Perhaps the largest of these concerns is the role of ice concentration in determining the spread and trajectories of spilled ocean pollutants and in determining the technologies to be used when attempting the mitigation of the effects of spilled pollutants. Other areas of interest include the availability of ice to be used as resting platforms of sea mammals and the occurrence of open water to be used as feeding areas by birds.

The characterization of ice conditions clearly must be done by some -- statistical means. The normal approach to this sort of problem would be to compute the average concentration at various times. However, averaged data often tend to hide persistent trends or bimodal behavior patterns. Another calculation which can be performed is the determination of the dominant ice condition; i.e., the ice concentration category which occurs more than 50% of the time. This can be particularly important in terms of very high or very low ice concentrations. For instance, in an area with an average ice concentration between 26 and 50%, it would be very useful to know that on 50% of all occasions, the ice concentration was actually between 0 and 10%. This gives a much clearer picture of ice conditions which one might expect to encounter at that location.

*Outer Continental Shelf Environmental Assessment Program

This report contains maps of average ice concentration and dominant ice concentration for the Alaskan **Beaufort Sea** coast for one week of data sampled every other week between mid June and **early** October. Then, based on these maps, a series of derived maps have been produced indicating the most **likely** ice conditions to be met at each of these times.

DATA

Digitized maps of sea ice concentration were prepared from NOAA/Navy Joint Ice Center Analysis charts for an area of the **Beaufort** Sea approximately 350x995 km (Figure 1). This area extends from **Wainwright** at 160° W on the coast of the **Chukchi** Sea to Hooper Island at 135° W in MacKenzie Bay. At 135° W the coverage extended north to 72° N; at 160° W it extended to approximately 73° 30' N. The northern border of the study area was selected to correspond approximately to **the** location of the most extreme retreat of concentrated ice pack that could be observed in the **period 1972-1981**. Thus the maps represent a comprehensive statistical analysis of all changes in ice concentration that were observed in the region rather than just a limited coverage of nearshore ice concentration changes.

Nine alternate one-week periods were selected starting with June **13-19 and ending** with October 3-10. This time span was adequate to document the time of the first significant appearance of open water in the spring, but insufficient to document the completion of freezeup in the fall for the regions of the study area in the **Chukchi** Sea and MacKenzie Bay. However, the time period is adequate to document the time of freezeup for most of the north coast of Alaska.

Ice concentration areas were digitized from each of the 89 individual maps in 5 km square elements in a grid of approximately 13,000 elements. Three kinds of maps were made: (1) nine average concentration maps (one for each one-week period) averaging the data from 10 years into four categories (0-20%, 30-50%, 60-70%, and 80-100% ice concentration); (2) nine dominant concentration maps documenting which of four ranges (0%, 10-50%, 60-90%, and 100% ice concentration) were present for 5 or more years at each grid element; and (3) nine open water presence maps derived by combining the average ice concentration and the dominance maps. A "no dominance" category covers the areas for which none of the previous categories were present for 5 or more years. Some properties of the "no dominance" category which should be taken into consideration when interpreting the maps are that the possible average ice concentrations can range from nearly ice-free to nearly 100%, and that in these cases at the high and low limits of average ice concentration, an element which falls into the "no dominance" category can be less variable as measured by standard deviation than one which falls into a category of specified dominance. Table 1 elaborates the characteristics of the 5 dominance categories in relationship to the four average concentration categories. Definitions of the open water presence categories are in Table 2. These categories group elements from the matrix of Table 1.

The NOAA/Navy charts based largely on Advanced Very High Resolution Radiometer (AVHRR) imagery, were expanded to a scale of $1:10^6$. The 5 km grid size used for digitization and computer calculation is somewhat small considering the scale of the primary data set. However, the maps were to be checked for accuracy against earlier Landsat-derived data for

which a 5 km grid was used. Landsat imagery (which has a resolution element of 80 meters) is especially suitable for the detection of inshore open water areas; however, the coverage is not as extensive or frequent as AVHRR imagery. If substantial agreement exists between the NOAA based maps presented here and earlier Landsat based maps, confidence will increase in the accuracy of the NOAA based maps in those areas for which NOAA-derived data is the only data available.

An analysis was conducted to determine how well earlier Landsat based data (Stringer, Bauman and Roberts, 1981, and Stringer, 1982) matches NOAA based data. For the averaged maps, precise agreement occurs only 50% of the time. This agreement is always in the inshore, and in the 0-25% ice concentration range. It should be kept in mind that because the NOAA data uses a larger resolution element than Landsat, as closely as the two types of data agree, the Landsat will be the more accurate of the two for really small open water patches and for really close inshore open water. Very often the Landsat-based concentration is a little less than the NOAA-based concentration.

For the dominance maps, agreement is better, and it occurs most of the time. Furthermore, agreement in the 0% concentration (open water) category is again the most frequent category of agreement.

Not surprisingly, earlier NOAA based data agrees very well with the current computer processed NOAA data whether this be the averaged data or the dominant data.

Thirty-eight inshore stations were selected for calculation of standard deviation as a measure of variability in ice concentration in the ten-year period. Standard deviations close or equal to zero are characteristic of deviations close or equal to the average; standard deviations approaching 50% are indicative of deviations grouping equally

at each extreme value. Obviously as the standard deviation approaches 50%, the average becomes less realistic in describing or predicting ice concentration. This is also true of the dominant concept; however, as the definition of dominant requires that at least five of the ice concentrations be in one of four categories (0%, 10-50%, 60-90%, 100%), the dominant categories are less susceptible to extreme variation. The dominant ice concentration maps were compiled to show regions where one ice concentration category was present at the sampling time for five or more years out of the ten-year observation period. The concentration ranges chosen for dominant categories were 0-9%, 10-50%, 51-90%, and 91-100%. These ranges were chosen because it was thought that they were more suited to describing dominant ice conditions than the ranges chosen for describing average ice concentration. Dominant ice concentration maps (especially the 0 and 100% categories are inherently more realistic in describing and predicting ice concentration than average concentration maps.

Table 2 lists the standard deviations from the average ice concentrations at 38 inshore grid elements. This table was constructed to give some semi-quantitative meaning to the necessity of considering the possibility of extreme variation of ice concentration from the average or the dominant at any time of the open water season when attempting to use the ice concentration maps in this paper.

The following observations can be made. The only period for which ice concentration has a normal statistical distribution and the average ice concentration maps have real validity is the month of June. This is because there are no large areas of open water. At this time of the year, any open water occurs in pockets of a size more suitable for detection by Landsat imagery than by NOAA imagery.

Significantly, as soon as open water appears **over large areas**, the standard deviations group in the 30-40% range and stay there for the whole **of** the open water season. This has two consequences. The average ice concentration maps become less meaningful, and when using the dominant maps, one must assume that the deviations from the dominant ice concentration **will** be extreme.

The week of October **3-10**, the onset of **freezeup**, is **also** unique. Thirty-five of the thirty-eight sites have standard deviations approaching **$\pm 50\%$** . This arises from the fact **in** roughly 5 of the **10** years the water was essentially open, while in the remaining years it was essentially ice covered. One must also draw the conclusion that once freezeup starts, it **proceeds** relatively rapidly, particularly when compared to the onset of breakup. **In** this period, one does not detect years with only partial open water inshore. Obviously, a large part of the average ice concentration map for this period is meaningless in the sense of **normal** interpretation. **It** really relates the fraction of years that the area is ice covered during this time period.

RESULTS

Attached as Appendix I is a series of data sets, each consisting of (1) an average ice concentration map, (2) a dominant ice concentration map, (3) an open water presence class map, and (4) a table listing average concentration and standard deviation and dominant ice concentration for each of thirty-eight stations in **the** study area, are presented for each of the nine one-week periods **during** the partial ice cover season.

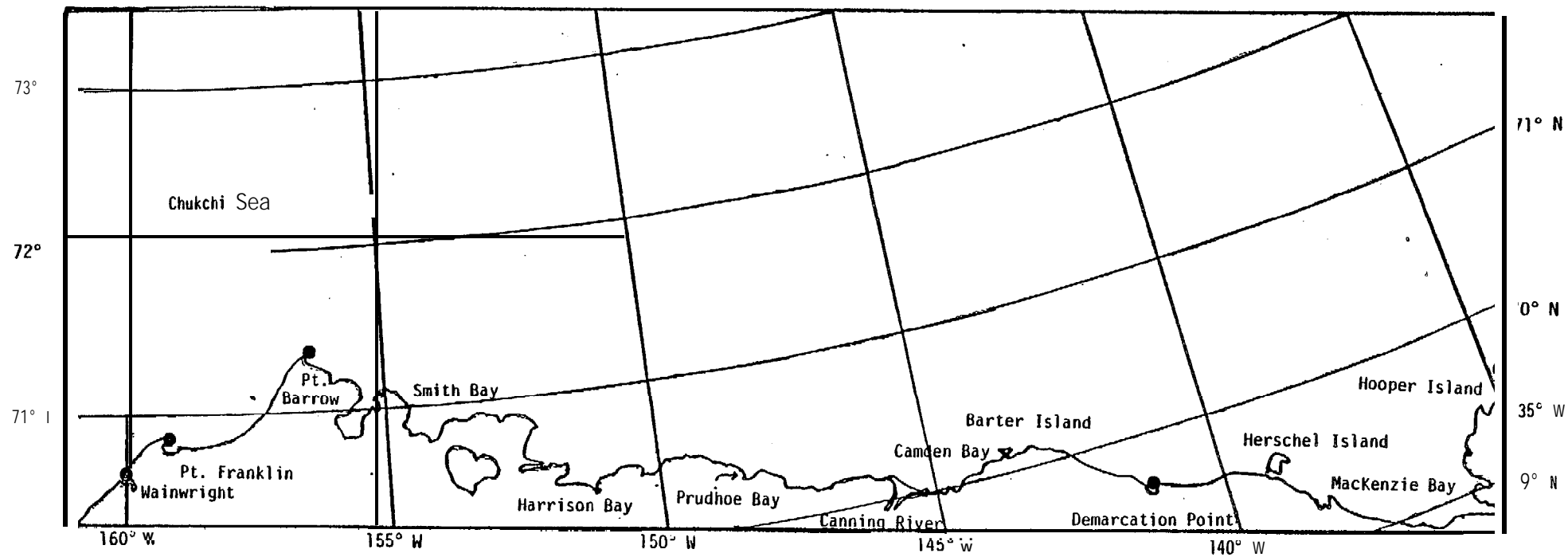


Figure 1. Geographic locations in the Beaufort and Chukchi seas.

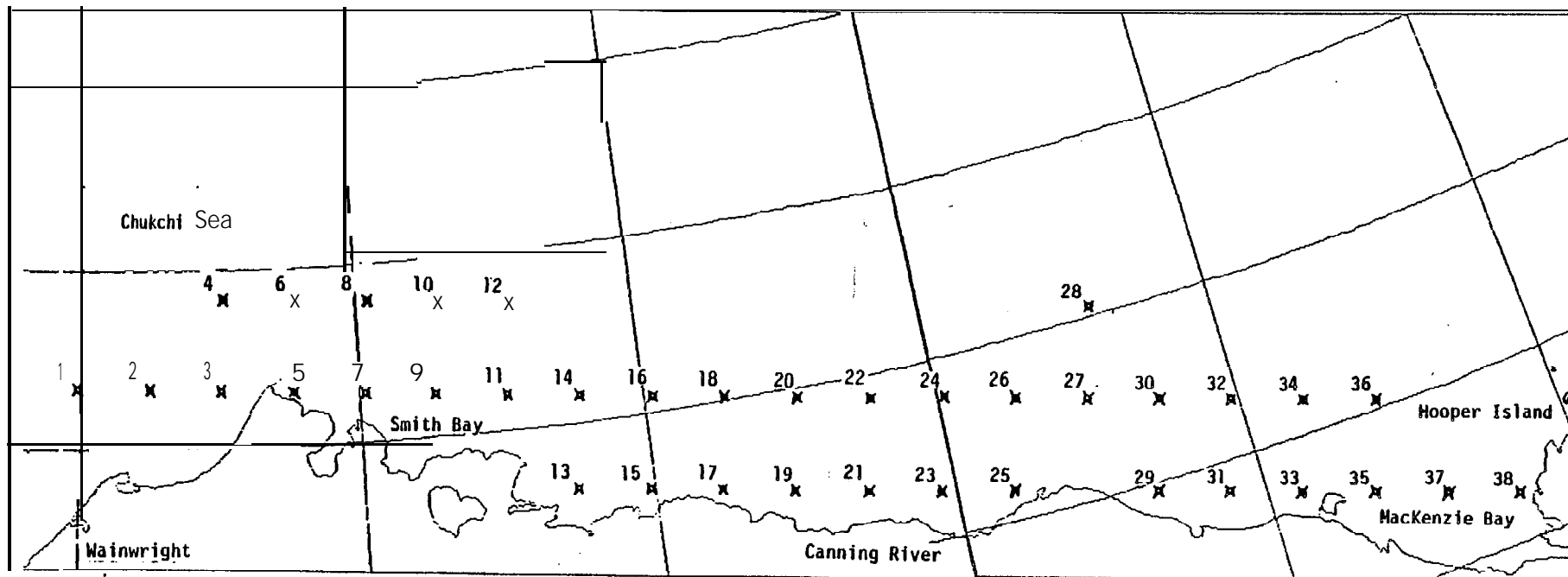


Figure 2. Location of sites for determination of standard deviation, average ice concentration, and dominant ice concentration.

TABLE 1: CHARACTERISTICS OF THE 5 DOMINANCE CATEGORIES USED IN THE DOMINANCE CLASSIFICATION SYSTEM
ICE CONCENTRATION CATEGORIES.

Average Concentration Categories: Definitions	Dominance Categories and Definitions				
	A	B	C	D	E
0-25% Average Ice Concentration	At least 5 years of 10 of 0-9% concentration	At least 5 years of 10 of 10, 20, 30, 40, or 50% concentration	At least 5 years of 10 of 40, 70, 80 and 90% concentration	At least five years of 10 of 91-100% concentration	10 dominance, less than 5 years of 10 in any category
	At least 50% chance of open water. At 25% conc. extreme, one could have 8 0-9% years if the remaining 2 were 100% or as many as 40% of the years were >50%	At least 50% chance of one being between 10 and 40%. At most open water will occur 40% of the time, and ice one. >50% will occur 30% of time			10% of the years must have ice conc. >5.0%. Open water must occur 10% of the time.
	OPEN WATER CLASS* (1)	OPEN WATER CLASS* (3)			OPEN WATER CLASS* (4)
26-25% Average Ice Concentration	At least 50% chance of open water. The more frequently open water occurs, the more frequently non-open water will be >50% At 50% conc. extreme, water will be open 50% of the time and 100% ice-covered water the remaining time.	At least 50% chance of ice conc. being between 10-50%. At most, open water will occur 10% of the time and water of 50% ice cover will 50% of the time.	At least 50% chance of ice conc. between 91-9(M). Open water is often as 40% of the time.		Open water can occur up to 40% of the time. At least 20% of years contain ice conc. of 50%
	OPEN WATER CLASS* (2)	OPEN WATER CLASS* (4)	OPEN WATER CLASS* (5)		OPEN WATER CLASS* (5)
51-75% Average Ice Concentration		At least 50% chance of ice conc. between 10-5(JX). Possible for open water to occur 10% of time. However, virtually all years not between 10-50% are >50%.	At least 50% chance ice conc. is between 51 and 90%. Ice conc. <50% can occur as frequently as 40% but open water is rare.	100% ice cover occurs at least 50% of the time. Open water possible up to 40% of the time. The more frequently open water occurs, the more frequently non-open water years will be >50%.	At least 20% of years contain ice conc. of 50%. At least 20% of years contain conc. <50%. The more frequently open water occurs, the more frequently remaining years will be >50% conc.
		OPEN WATER CLASS* (6)	OPEN WATER CLASS* (6)	OPEN WATER CLASS* (6)	OPEN WATER CLASS* (6)
76-10(XL) Average Ice Concentration			At least 50% chance ice conc. is between 51-90%. Possible for open water 20% of the time, but 100% ice conc. can occur 40% of the time.	100% ice cover at least 50% of the time. Possible for open water 20% of time, but practically speaking, many sites of Dominant and Average ice Concentration are 100% ice covered 100% of the time.	Two years must have conc. <50%. 100% conc. must occur 40% of the time.
			OPEN WATER CLASS* (6)	OPEN WATER CLASS* (7)	OPEN WATER CLASS* (7)

*OPEN WATER CLASS is a subjective evaluation of the probability of finding open water (ice concentration <10%);
(1) is most favorable; (7) is least favorable

TABLE 20 DETAILED EXPLANATION OF OPEN WATER CLASSES.

Open Water Class 1	High Frequency of open water (0 to <10% concentration) This is the most favorable region for open water. At least 50% of the time (and possibly more frequently) open water has been present. High concentration ice years are possible, but rare; non-open water conditions tend to the light ice concentrations.
Open Water Class 2	High Frequency of open water (0 to <10% concentration) at least 50% of the years were characterized by open water. The non-open water years were characterized predominantly by ice concentrations >50% .
Open Water Class 3	High frequency of open water or ice concentration <50%. At least 50% of the time, the ice concentration is between 10 and 50%. As many as 4 years could have been open water. Ice concentrations >50% are rare.
Open Water Class 4	Possible presence of open water (0 to <10% concentration) at least 50% of the time the ice concentration will be <50% ; ice concentrations >50% are infrequent.
Open Water Class 5	Possible Presence of open water (0 to <10% concentration) Open water can occur 40% of the time. Open water and low ice concentrations are frequent, but the more frequently they occur the more likely the remaining years will be greater than 50%.
Open Water Class 6	High frequency of ice concentration (greater than 50%) open water rare.
Open Water Class 7	High frequency of 100% ice concentration.


TABLE 3. RANGE OF STANDARD DEVIATIONS FOR THIRTY-EIGHT INSHORE 5 KM² GRID ELEMENTS


Time Period	Number of Ice Concentrations Found in the Ranges of Standard Deviations Listed					conspicuous Events of the Ice-Free Season
	<u>±0-10%</u>	<u>±11-20%</u>	<u>±21-30%</u>	<u>±31-40%</u>	<u>>±40%</u>	
June 13-19	17	1	6	5	9	Mostly frozen throughout the entire area
June 27-July 3	23	0	0	13	2	
July 11-17	14	2	6	8	8	
July 25-31	2	4	6	17	9	First appearance of open water as the dominant ice concentration along most of the coast
August 8-14	5	2	11	19	1	
August 22-28	2	3	5	21	7	First appearance of open water as the dominant ice concentration along the entire coast
September 5-12	3	4	10	12	9	
September 19-26	1	0	12	22	3	Maximum extent of open water as the dominant ice concentration
October 3-10	0	0	0	3	35	Freezeup begins


APPENDIX I.


Ice concentration data sets on the following pages are 9 data sets describing summertime ice concentrations in the Beaufort Sea. Each data set consists of: a) an average ice concentration map; b) a dominant ice concentration map; c) an open water presence map; d) a table of ice indices at specific locations; and e) a discussion of the data for that time period. The legend for the average and dominant ice concentration maps contained in this series is given below.

a. Average Ice Concentration Maps (top map of each figure)


 0 - 25%


 26 - 50%


 51 - 75%


 76 - 100%


b. Dominant Ice Concentration Maps (bottom map of each figure)

 0 - 9%

 10 - 50%

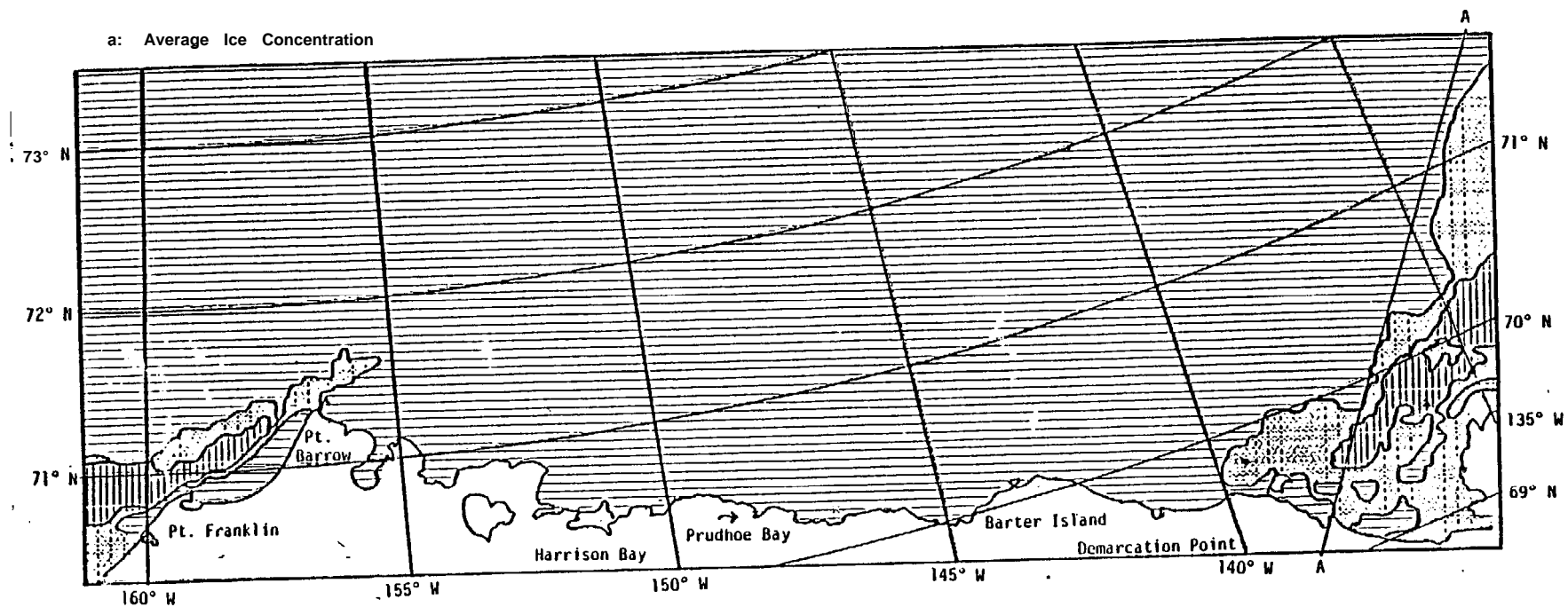
 51 - 90%

 91 - 100%

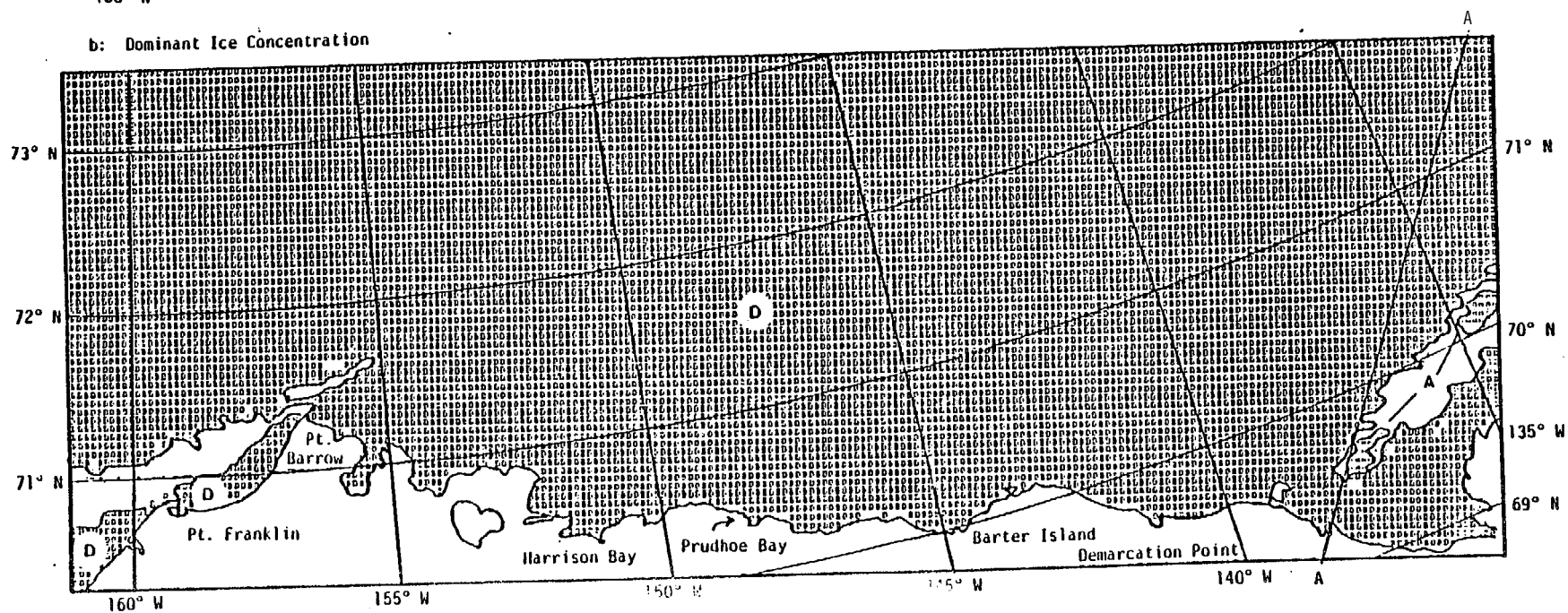
 No particular ice concentration category was present on 50% or more occasions

Ice Concentration June 13-19, 1972, 1975-81

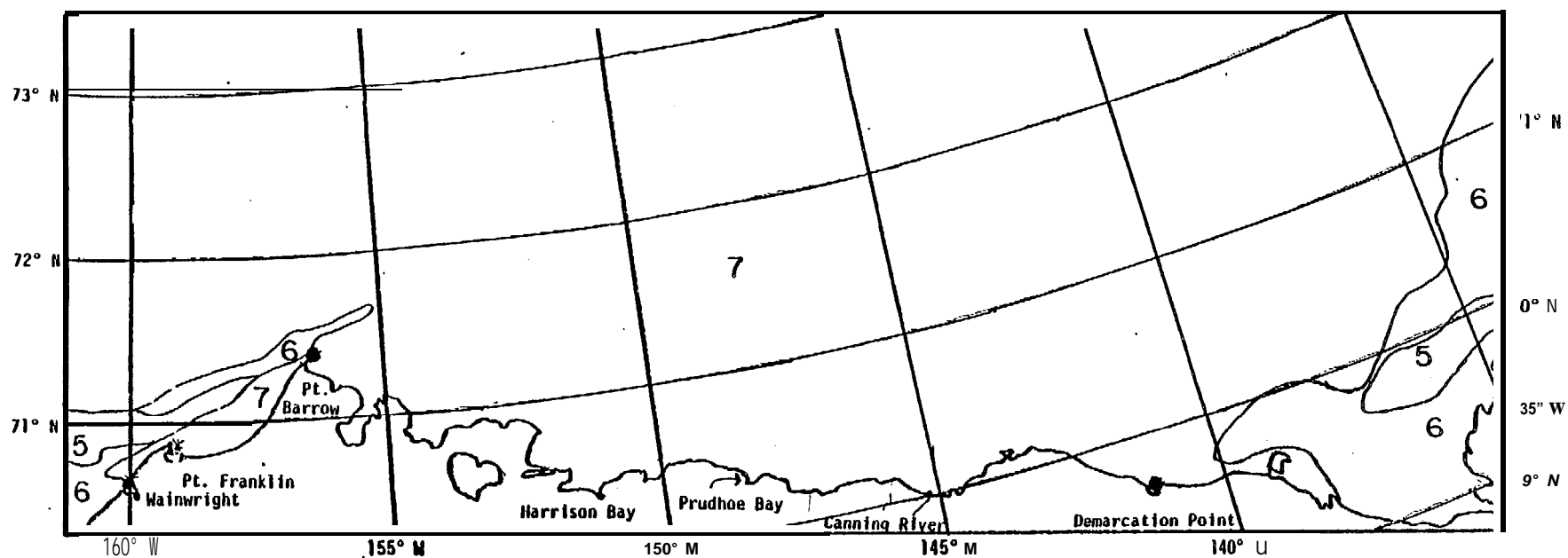
a: Average Ice Concentration



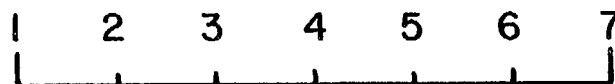
b: Dominant Ice Concentration



c: Open Water Presence for June 13-19



Most Favorable
Circumstance for
Open Water



Least Favorable
Circumstance for
Open Water

d: SUMMARY OF AVERAGE ICE CONCENTRATION AND STANDARD DEVIATION AND
DOMINANT ICE CONCENTRATION AT THIRTY-EIGHTS ELECTED STATIONS
FOR JUNE 13-19.

Station Number	Ice Concentration Average	Standard Deviation from Concentration Average	Ice Concentration Category Dominant
		33%	100%
2	76	43	100
3	60	47	no dominance
4	99	3	100
5	90	30	100
6	99	3	100
7	89	30	100
8	92	20	100
9	100	0	100
10	99	33	100
11	100	0	100
12	99	3	100
13	79	42	100
14	99	3	100
15	79	42	1 0 0
16	100	0	100
17	79	42	100
18	100	0	100
19	90	30	100
20	99	3	100
21	90	30	100
22	100	0	100-
23	90	30	100
24	100	0	100
25	79	42	100
26	100	0	100
27	100	0	100
28	100	0	100
29	79	42	100
30	100	0	100
31	89	33	100
32	100	0	100
33	72	44	100
34	89	33	100
35	67	43	100
36	89	22	100
37	75	38	100
38	80	39	100

e: Mid June (Data obtained between June 13 and 19)

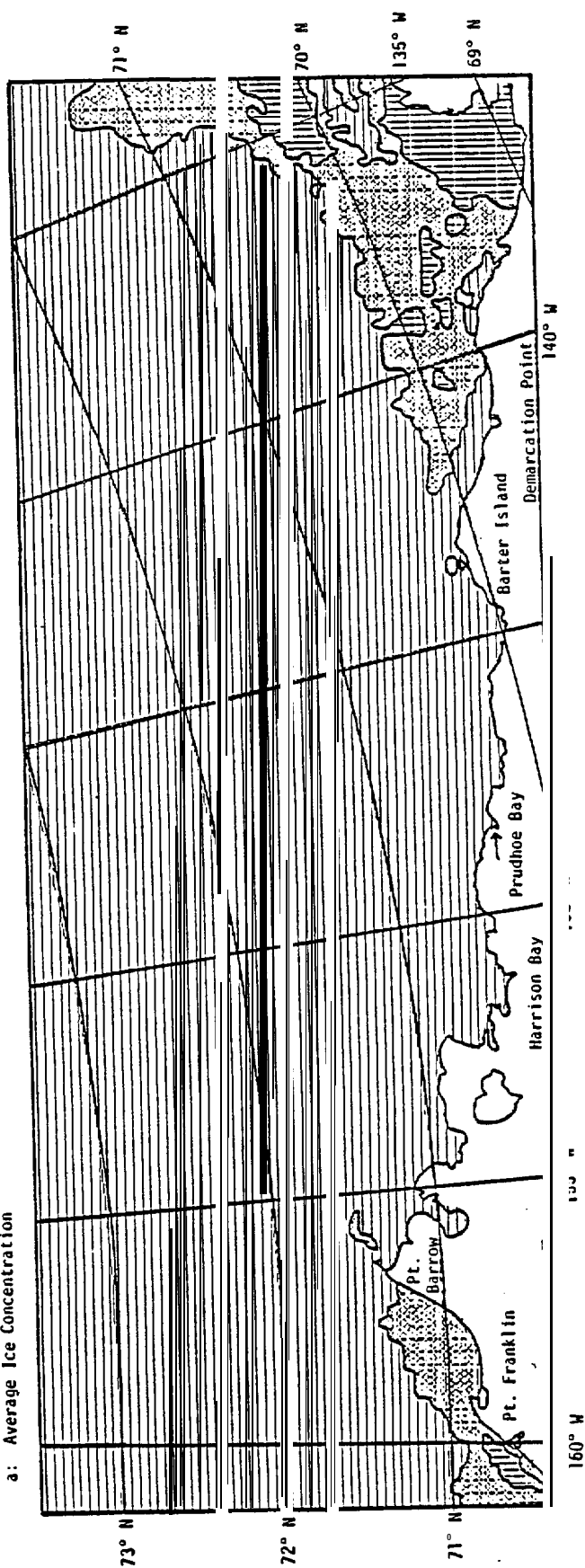
The Alaskan sector of the Beaufort Sea is still largely ice-bound at this time. Only a small part of inner Harrison Bay has an average ice concentration less than 75%. However, large scale melting and break-up has taken place in the Chukchi Sea to the west and in the MacKenzie Bay area to the east.

In terms of dominant ice conditions, the 91-100% category is prevalent throughout the study area. Only in the extreme east and west is any other dominance category found and there that category is the "no dominance" category. This indicates that a wide variety of ice concentrations are to be found in these areas.

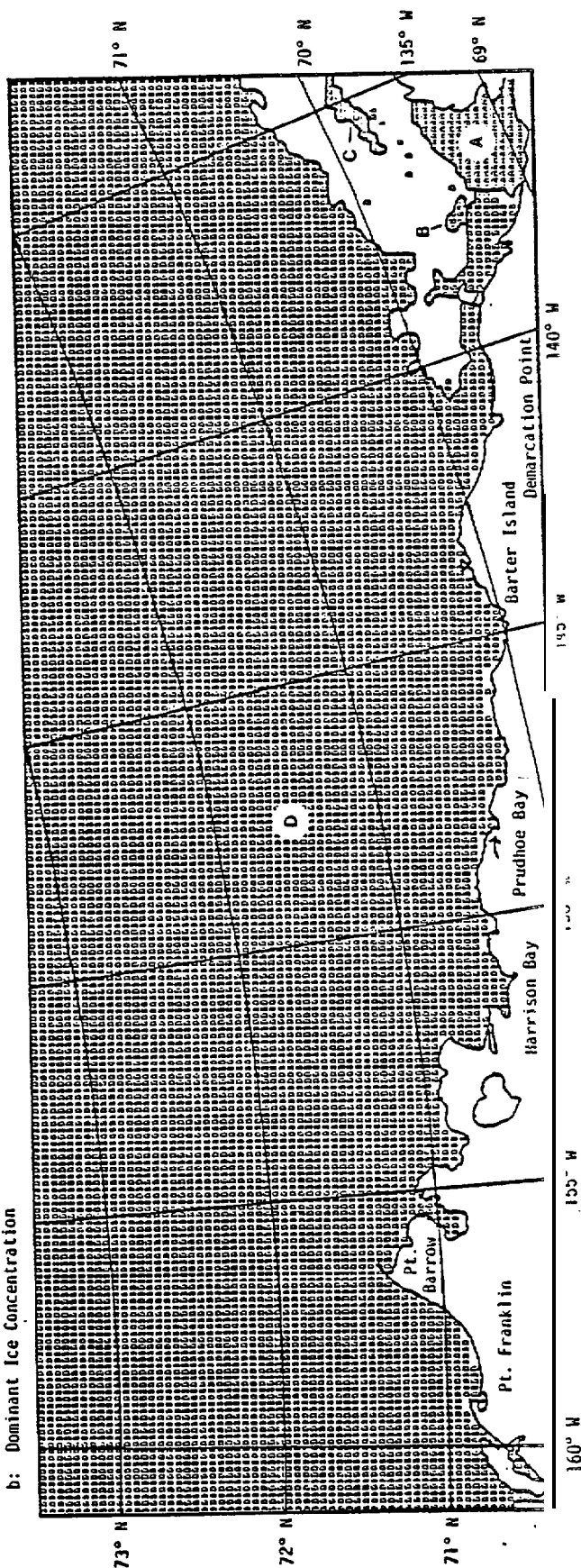
Finally, part d gives in tabular form the average ice concentration and standard deviation and dominant ice concentration at thirty-eight selected stations (illustrated in Figure 2). Inspection of these data show that the concentration values at inshore locations possess a large standard deviation while those further offshore have considerably larger standard deviations. Examination of the original data sets showed that the ice concentration in these areas tended to be very high most years and very low one or two years. As a result, both the average and dominant categories are high concentration values, yet the standard deviation is large. This, in turn, indicates that early season ice is removed largely in near shore areas on the Alaskan Beaufort coast by melting in place, leaving large pools of open water rather than by a physical breaking-up of the ice, resulting in a range of ice concentrations.

Ice Concentration on June 27-July 3, 1972-83

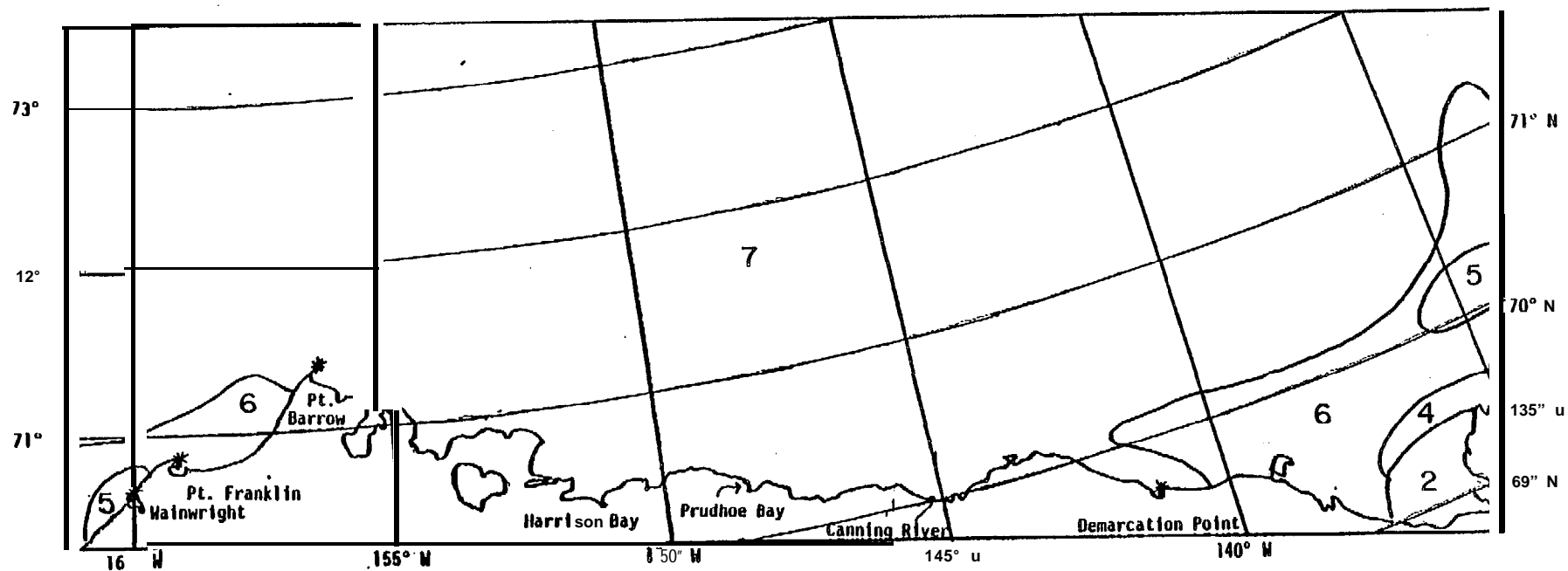
a: Average Ice Concentration



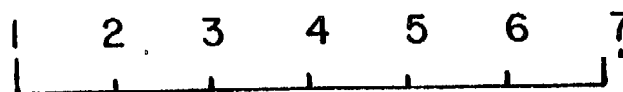
b: Dominant Ice Concentration



c. Open Water Presence for June 27-July 3



Most Favorable
Circumstance for
Open Water



Least Favorable
Circumstance for
Open Water

d. SUMMARY OF AVERAGE ICE CONCENTRATION AND STANDARD DEVIATION AND DOMINANT ICE CONCENTRATION AT THIRTY-EIGHT SELECTED STATIONS FOR JUNE 27-JULY 3.

Station Number	Ice Concentration Average	Standard Deviation from Concentration Average	Ice Concentration Category Dominant
	98%	4%	100%
2	98	4	100
3	73	40	100
4	98	4	100
5	89	31	100
6	98	4	100
7	76	42	100
8	99	3	100
9	97	9	100
10	99	35	100
11	96	10	100
12	99	3	100
13	100	0	100
14	96	10	100
15	100	0	100
16	99	3	100
17	100	0	100
18	99	3	100
19	90	32	100
20	99	3	100
21	82	38	100
22	99	3	100
23	82	38	100
24	99	3	100
25	82	38	100
26	97	7	100
27	95	8	100
28	99	3	100
29	75	40	100
30	95	8	100
31	58	40	no dominance
32	97	7	100
33	66	39	100
34	74	40	100
35	72	31	no dominance
36	70	39	100
37	44	40	10-50
38	31	41	0

e. Late June/Early July (June 27 - July 3)

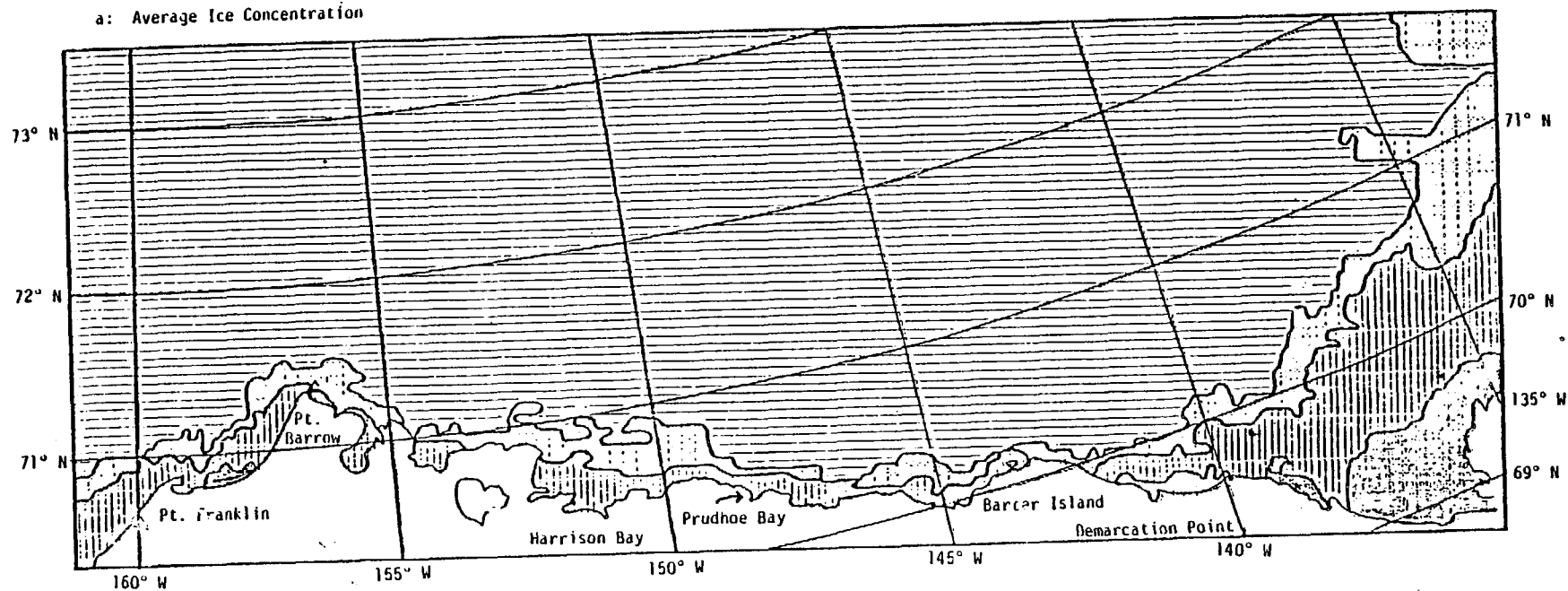
Ice Concentration in the Alaskan sector of the Beaufort Sea coast remains in the 75-100% range.

These maps also show that break-up in terms of fractured ice concentrations occurs both in the Chukchi Sea to the west and in the Mackenzie Bay area to the east before it occurs in the Alaskan sector of the Beaufort Sea.

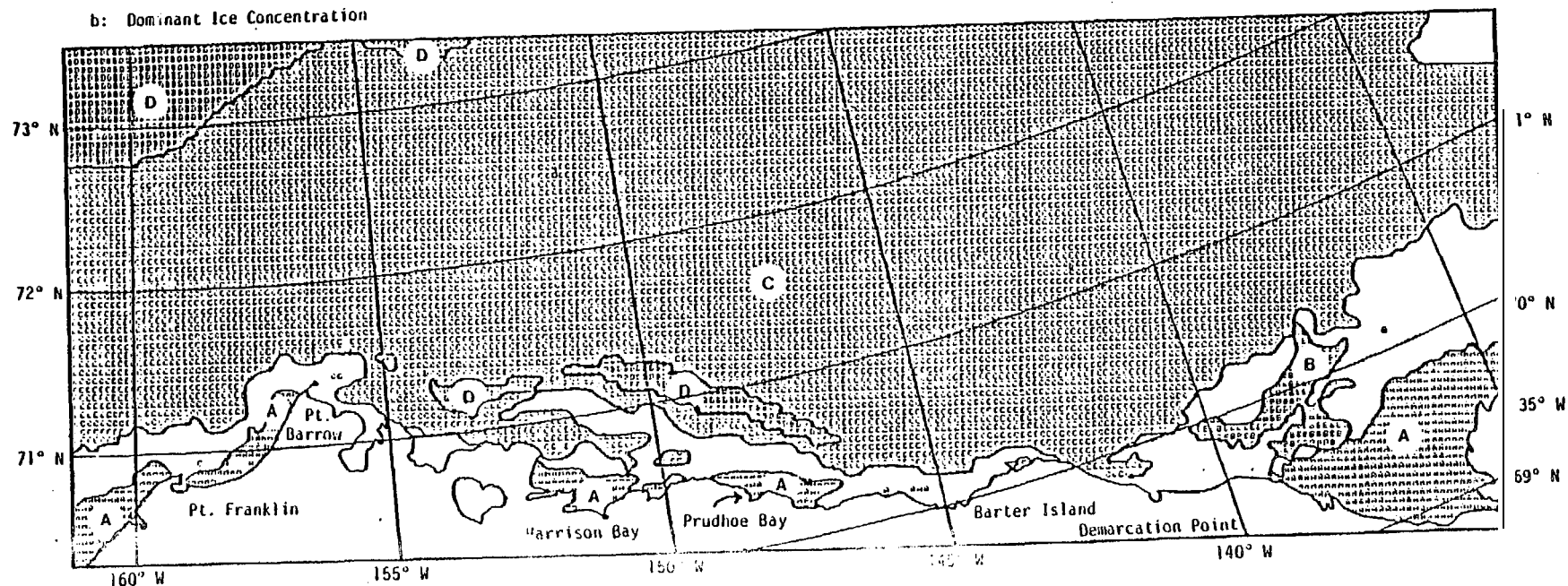
Examination of the standard deviation data shows several sites along the entire Beaufort coast with a high standard deviation from the average concentration. In the Alaskan sector this occurred primarily because, although on most years a very high concentration occurred, on one or two, a very low ice concentration occurred. In the Canadian sector the high standard deviation arose because on most years, low ice concentrations occurred; on one or two years, very high concentrations occurred.

Ice Concentration July 11-17, 1971

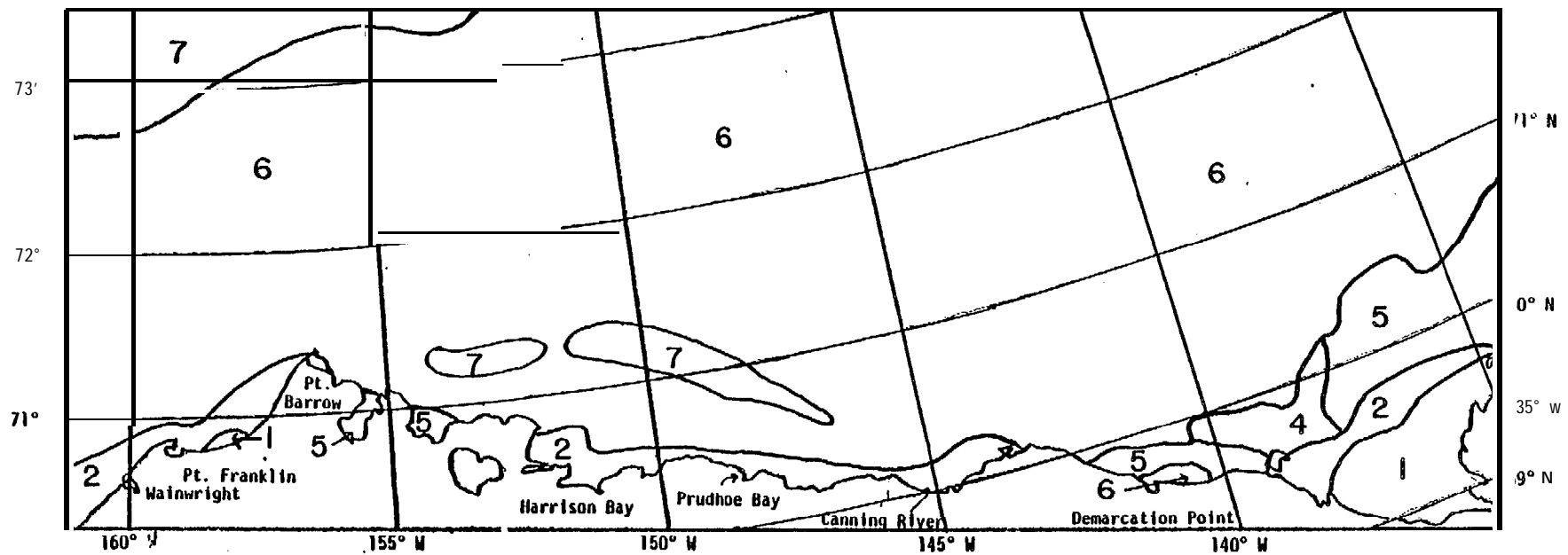
a: Average Ice Concentration



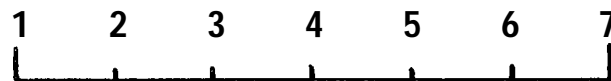
b: Dominant Ice Concentration



c. Open Water Presence for July 11-17



Most Favorable
Circumstance for
Open Water



Least Favorable
Circumstance for
Open Water

d. SUMMARY OF AVERAGE ICE CONCENTRATION AND STANDARD DEVIATION
AND DOMINANT ICE CONCENTRATION AT THIRTY-EIGHT SELECTED STATIONS
FOR JULY 11-17.

Station Number	Ice Concentration Average	Standard Deviation from Concentration Average	Ice Concentration Category Dominant
2	94	5	51-90
3	69	42	no dominance
4	94	5	51-90
5	50	47	no dominance
6	94	5	51-90
7	88	21	51-90
8	94	5	51-90
9	95	5	51-90/100*
10	94	5	51-90
11	95	5	51-90/100*
12	94	5	51-90
13	47	46	no dominance
14	94	5	51-90
15	54	42	no dominance
16	95	5	51-90/100*
17	60	44	no dominance
18	94	5	51-90
19	71	40	no dominance
20	91	9	51-90
21	89	14	51-90
22	84	30	51-90
23	70	39	51-90
24	84	14	51-90
25	54	45	no dominance
26	84	30	51-90
27	77	34	51-90
28	84	30	51-90
29	52	43	no dominance
30	92	6	51-90
31	43	40	no dominance
32	87	21	51-90
33	53	44	no dominance
34	79	26	no dominance
35	29	37	0
36	50	37	10-50
37	23	38	0
38	11	31	0

* Five years were within the 100% dominant ice concentration category, and the remaining five years were within the 60-90% dominant ice concentration range.

e. Mid July (July 11 - 17)

By this time significant changes in the average ice concentration have taken place. Average concentrations as low as the 26-50% range are to **be** found along much of the Alaskan Beaufort coast--largely in **embay-**ments. Offshore from this is a band of 51-75% ice concentration extending (with a few small breaks) **along** the entire coastline. Beyond this the average ice concentration remains in the 76-100% category. Note that the headlands generally extend into the offshore band of **51-**75% concentration.

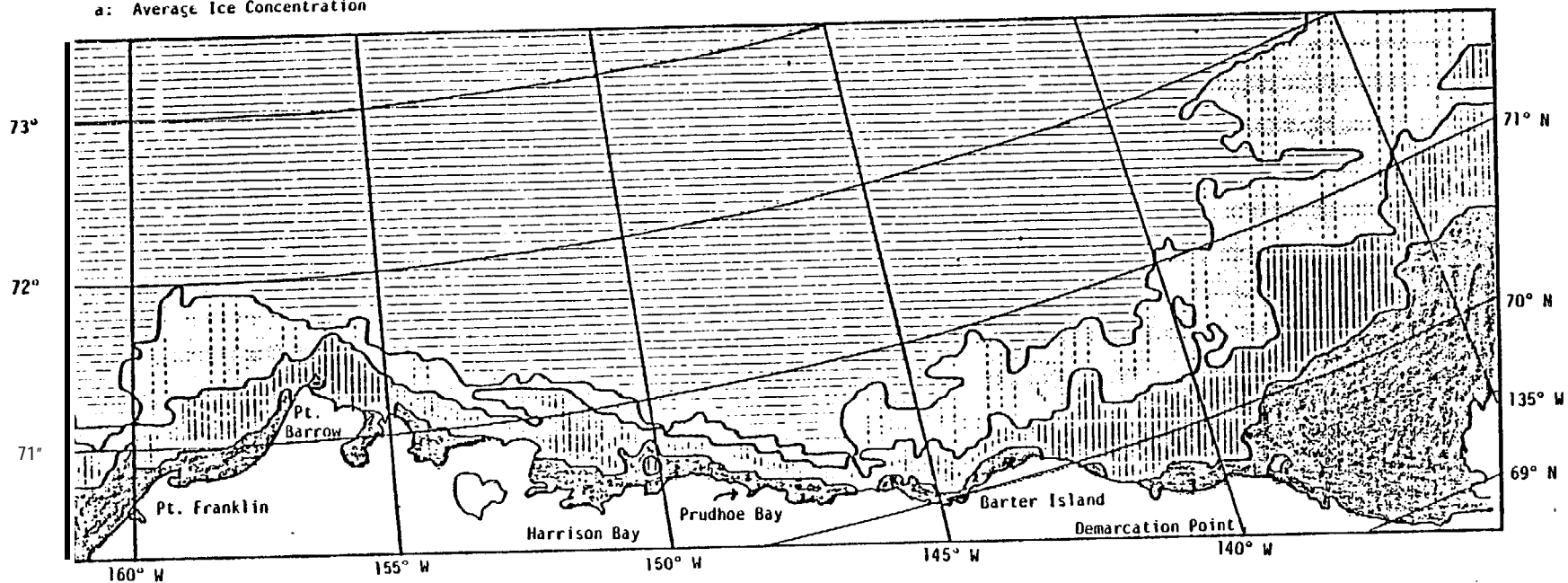
The dominant concentration map shows only two major pockets of **0-**10% concentration in the Alaskan sector of the **Beaufort** Sea. These are located in Harrison Bay and-in the Prudhoe Bay region. There are no significant areas where ice concentrations in the 10-50% category dominate. However, there are large areas of "no dominance" category located between the areas dominated by **0-9%** concentration and 51-90% concentration. The standard deviation from the average concentration at the selected sampling stations located within this area is around 45% in nearly all cases. With an important exception (to be discussed later) the remainder of the Alaskan Beaufort Sea is dominated by ice of 51-90% concentration. This is primarily a reflection of the large number of fractures in the ice cover which has occurred and not refrozen by this time.

Finally, there is a feature seen on the dominant concentration map worthy of some attention. This is the two part band of 91-100% dominant concentration in outer Harrison Bay. In other reports (Stringer, Barrett, and Schreures, 1980; Stringer **1974**) we have taken note of a greatly increased frequency of massive ridges in these locations. These ridges

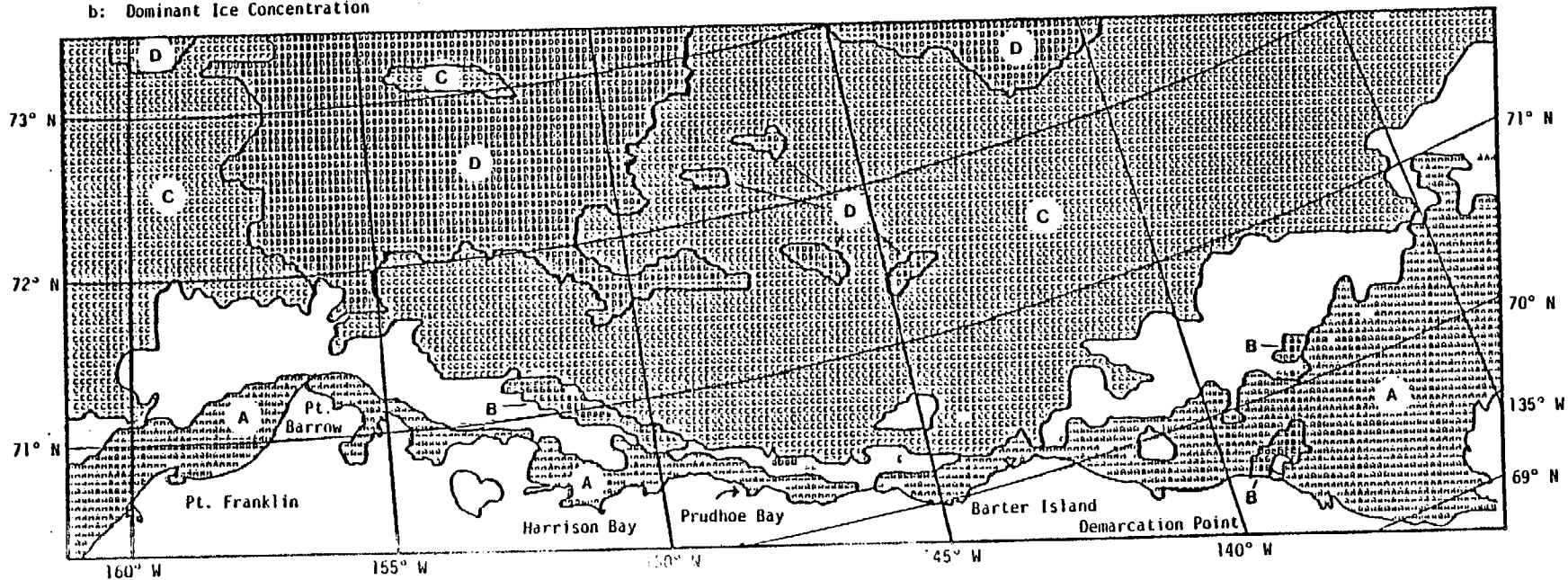
are at least in part grounded on shoals located in this area and tend to remain intact as the floating ice in the vicinity breaks up.

Ice Concentration July 25-31, 1972-81

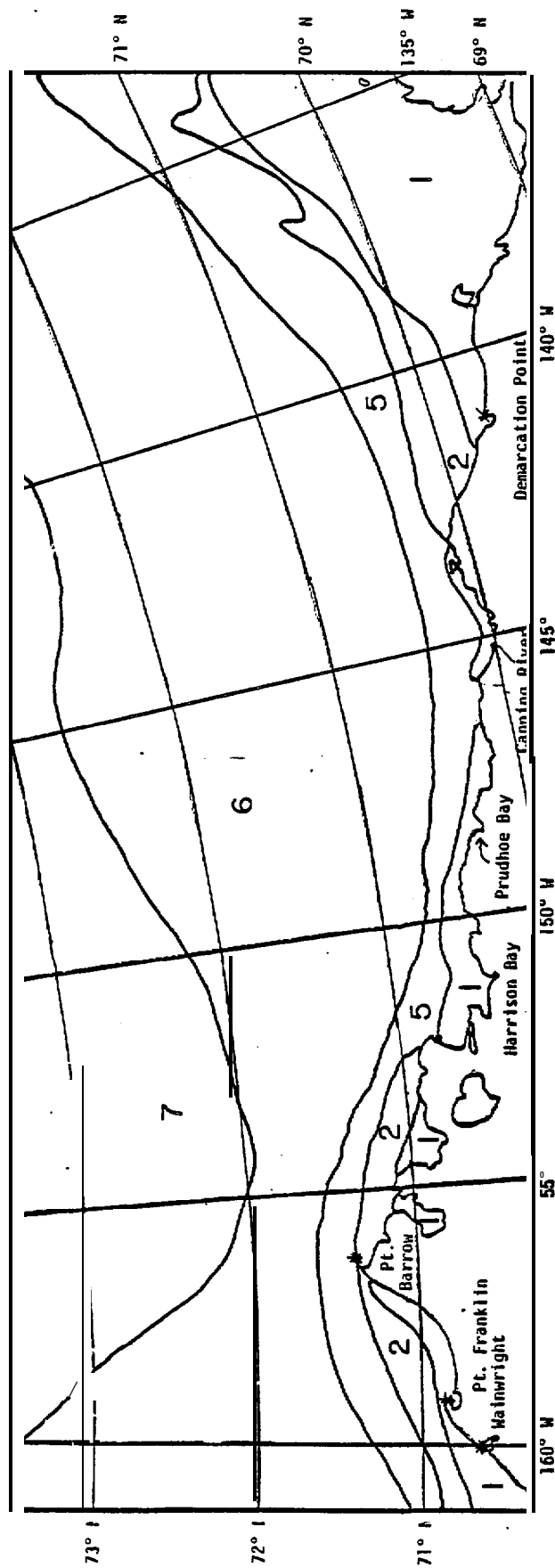
a: Average Ice Concentration



b: Dominant Ice Concentration



c: Open Water Presence for July 25-31



Most Favorable
Circumstance for
Open Water

2 3 4 5 6 7

Least Favorable
Circumstance for
Open Water

d. SUMMARY OF AVERAGE ICE CONCENTRATION AND STANDARD DEVIATION
AND DOMINANT ICE CONCENTRATION AT THIRTY-EIGHT SELECTED
STATIONS FOR JULY 25-31.

Station Number	Ice Concentration Average	Standard Deviation from Concentration Average	Ice Concentration Category Dominant
1	78%	32%	51-90%
2	57	45	no dominance
3	44	48	no dominance
4	72	36	51-90
5	27	44	0-9%
6	7	30	no dominance
7	44	42	no dominance
8	84	25	51-90
9	56	40	no dominance
10	91	12	51-90
11	56	37	10-50
12	91	12	51-90
13	11	19	0-9
14	73	32	51-90
15	31	44	0-9
16	84	23	51-90
17	22	32	0-9
18	76	35	51-90
19 "	29	29	10-50
20	79	33	51-90
21	52	38	no dominance
22	83	30	51-90
23	45	38	no dominance
24	78	31	51-90
25	19	31	0-9
26	69	31	51-90
27	62	43	51-90
28	83	30	51-90
29	34	42	0-9
30	68	39	51-90
31	30	37	0-9
32	55	48	no dominance
33	25	38	0-9
34	38	42	no dominance
35	11	19	0-9
36	16	32	0-9
37	0	0	0-9
38	0	0	0-9

e. Late July (July 25 - 31)

The average concentration map shows 0-25% ice concentration in most near shore areas. Exceptions are found adjacent to headlands where a continuous band of 26-50% concentration touches shore. Beyond this band is another continuous band--not touching shore anywhere--of 51-75% average concentration. Finally, beyond this, the major portion of the Beaufort Sea is in the zone of 76-100% average concentration.

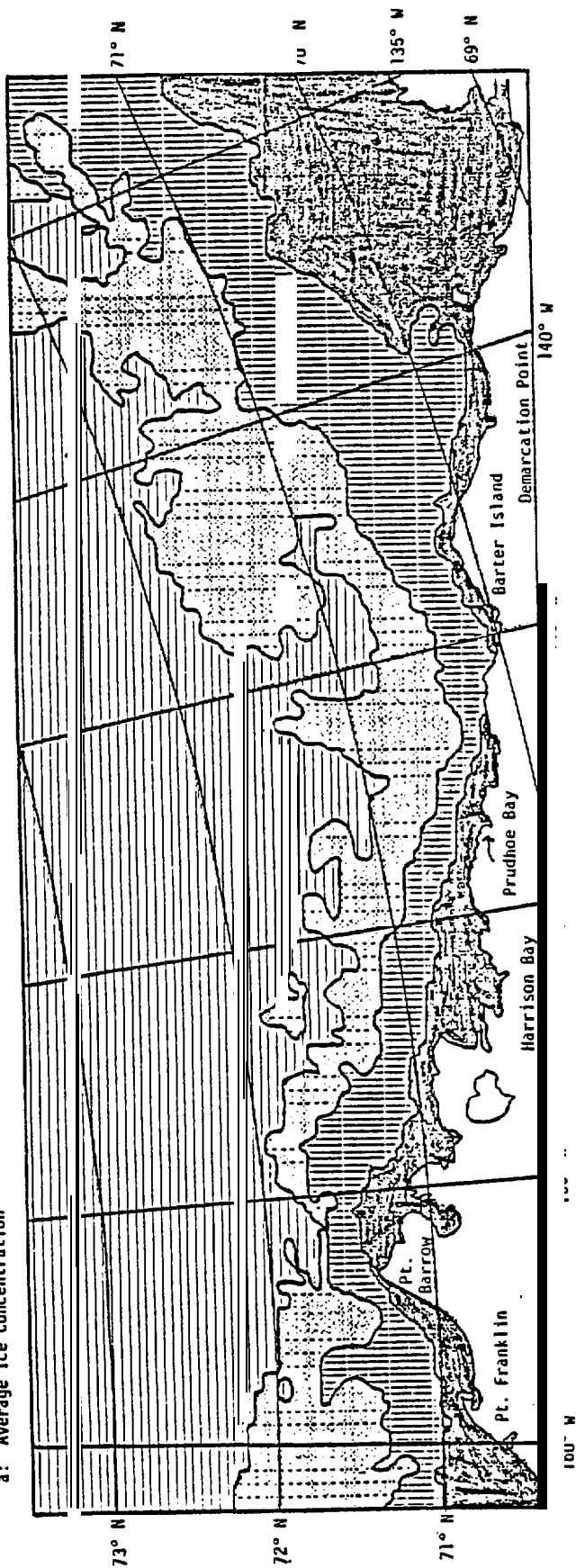
The dominant concentration map shows an interesting feature in that a region of 0-9% dominant concentration is found along the Beaufort Sea coast roughly coinciding with the area of 0-25% concentration shown on the average concentration map. However, in many areas the extent of the 0-9% dominant concentration is greater than the 0-25% average concentration. Although this result is statistically acceptable, it requires the standard deviation in ice concentration to be rather large at locations within the 0-9% dominant concentration but outside the 0-25% average concentration. The values listed in part d support this supposition.

It is interesting to note the relatively small area of the "no dominance" category. This time of the year, this is the region with the greatest variation in ice concentration and therefore is the area of least predictability.

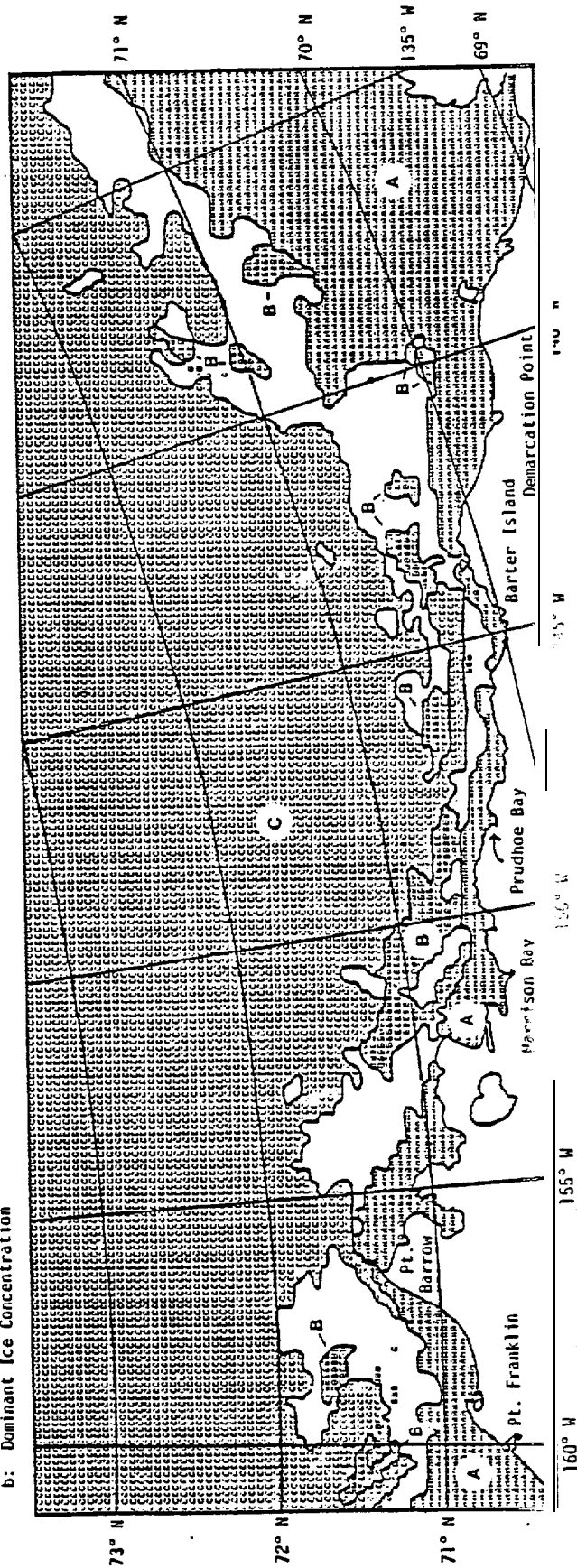
The open water presence map shows the first appearance of the most favorable category of open water for the summer season off the coast of Alaska. It duplicates to a certain extent the pattern of the average concentration map except that it better documents the difficult ice conditions close inshore that are potential impediments to shipping activities. The areas of interest are Pt. Barrow, Cape Halkett and the Canning River.

Ice Concentration A g = 8- 4, 1972-81

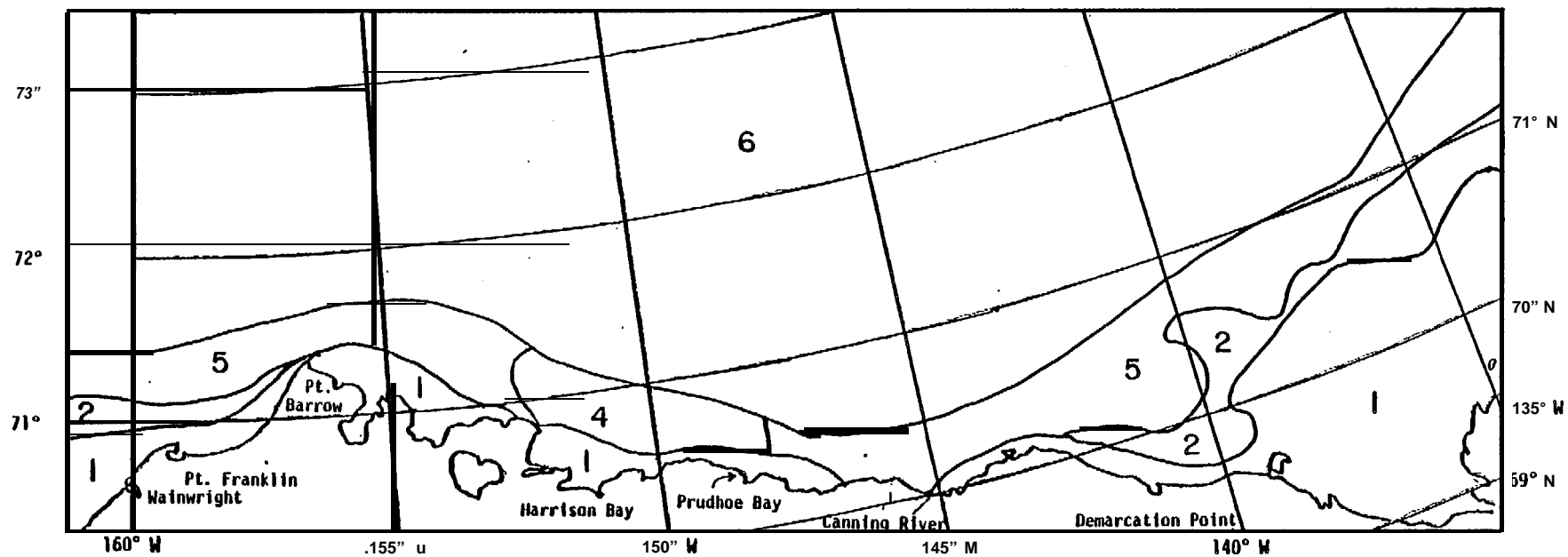
a: Average Ice Concentration



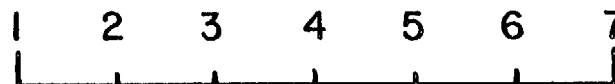
b: Dominant Ice Concentration



c. Open Water Presence for August 8-14



Most Favorable
Circumstance for
Open Water



Least Favorable
Circumstance for
Open Water

d. SUMMARY OF AVERAGE ICE CONCENTRATION AND STANDARD DEVIATION
AND DOMINANT ICE CONCENTRATION AT THIRTY--EIGHT SELECTED STATIONS
FOR AUGUST 8-14.

Station Number	Ice Concentration Average	Standard Deviation from Concentration Average	Ice Concentration Category Dominant
1	60%	33%	51-90%
2	38	36	no dominance
3	45	33	no dominance
4	74	25	no dominance
5	6	10	0-9
6	76	25	51-90
7	15	23	0-9
8	57	34	51-90
9	27	33	no dominance
10	63	35	51-90
11	57	33	10-50
12	76	28	51-90
13	10	19	0-9
14	65	33	no dominance
15	10	12	0-9
16	67	28	51-90
17	6	10	0-9
18	71	26	51-90
19	27	29	no dominance
20	77	27	51-90
21	55	26	51-90
22	67	38	51-90
23	48	33	51-90
24	73	30	51-90
25	32	35	no dominance
26	62	38	51-90
27	52	42	no dominance
28	69	40	51-90
29	22	34	0-9
30	43	39	no dominance
31	25	34	0-9
32	34	38	no dominance
33	15	23	0-9
34	31	39	0-9
35	3	9	0-9
36		32	0-9
37	0	0	0-9
38	0	0	0-9

e. **Mid August (August 8 - 14)**

The band of 0-25% average ice concentration has broadened and now extends nearly the entire **length** of the Alaskan **Beaufort** coast. The only break occurs along the promontory containing the Canning River **Delta**. Offshore from this zone is a continuous band of 26-50% average ice concentration. Next, even further offshore is a continuous band of 51-75% average ice concentration. Finally, there is a region of 76-100% average ice concentration. Although the boundaries between all other bands are somewhat smooth, the boundary between the 51-75% region and the 76-100% region is highly irregular.

The dominant ice concentration map exhibits a great deal more irregularity than the average ice concentration map. At this time no area is dominated by the 91-100% concentration category and only a small discontinuous band near shore is dominated by the 0-9% category. Note that the 0-9% dominant concentration category has a smaller gap at the Canning River mouth than does the 0-25% average concentration category. Here we have very low dominant concentrations and considerably higher concentrations. This indicates that **low** concentrations are most often found here but that departures from this norm consist of very high concentrations. A different situation is found at Cape **Halkett** on the **west** side of Harrison Bay. Here there is a gap in the **0-9%** dominant ice category but not in the 0-25% average concentration category. **Fur-**
thermore, no concentration category dominates in this gap. See Table 1 for a description of the range of concentrations and occurrences this implies.

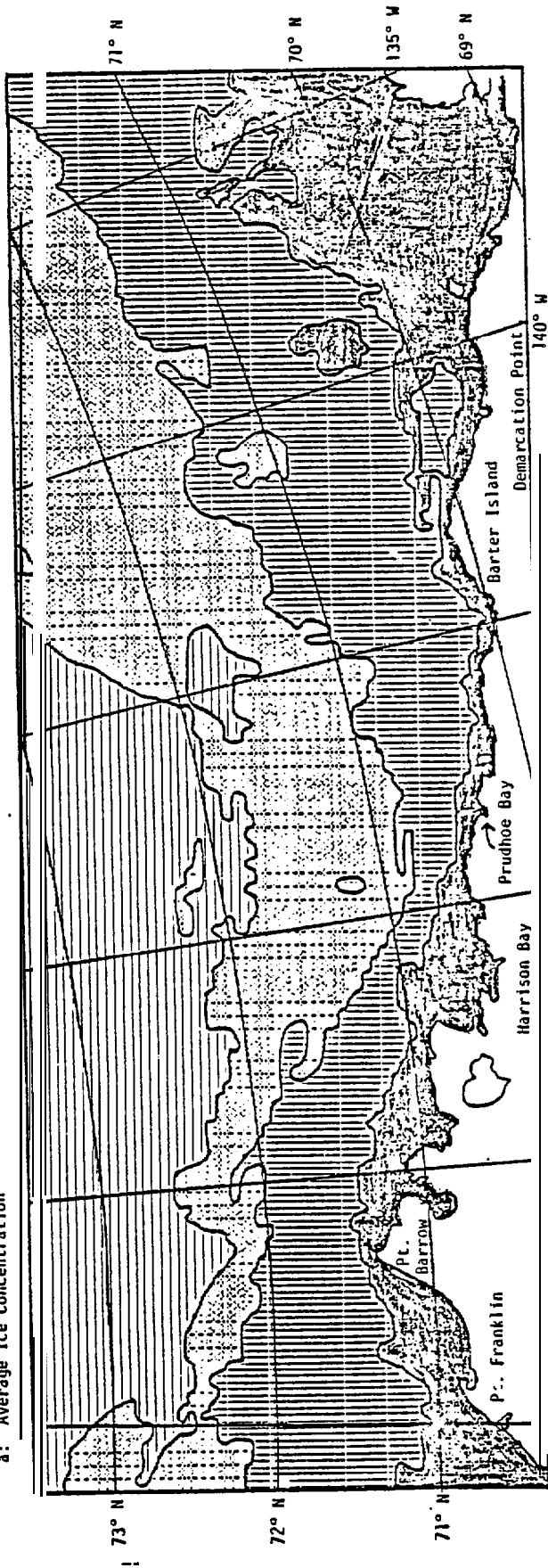
It is interesting to observe that at point 13, in the center of Harrison Bay, the dominant ice category is 0-9% and the average ice concentration is 10%, yet the standard deviation is 19%. Thus, even as late as the middle of August the center of Harrison Bay cannot be guaranteed to be ice free.

Open water presence map c reveals that the most favorable open water class has increased in size over late July. However, the continuity of these open water areas has remained essentially the same as existed for late July.

A statistical study of the summertime ice edge in the Beaufort and Chukchi seas (Stringer and Groves, 1985) reveals that for the week of August 10-16, there is a higher frequency of having some ice present in a band trending to the NW from the Canning River Delta than exists for the surrounding water. This study differentiated only between completely ice-free water and water containing ice; nevertheless, there seems to be a definite tendency for ice to remain in higher concentration in this location. Part of this band includes Weller Bank.

Ice Concentration August 22-28, 1972-81

a: Average Ice Concentration



b: Dominant Ice Concentration

